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16. Abstract

The Texas Metropolitan Mobility Plan (TMMP) includes estimates of congestion derived from the regional transportation planning models. This report describes modifications to the output statistics to incorporate the effects of freeway entrance ramp metering, freeway incident management, arterial signal coordination and arterial street access management. The technique was applied to the base year models for the eight TMMP study regions. The technique uses locally available data and an Excel® spreadsheet-based process.

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INCORPORATING THE EFFECT OF OPERATIONAL IMPROVEMENTS

IN THE TEXAS CONGESTION INDEX ESTIMATION PROCESS

by

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Implementation Report 5-4853-01-1
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Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

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DISCLAIMER

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The engineer in charge was Tim Lomax, P.E., (TX, #54597).

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Hidalgo – Hidalgo Metropolitan Planning Organization
Houston – Houston-Galveston Area Council
Lubbock – Lubbock Metropolitan Planning Organization
San Antonio – Bexar County Metropolitan Planning Organization

This report, the methodology, and the calculation spreadsheets are the result of a team effort. Teresa Qu, David Schrank, Kevin Hall, Jim Benson, Pam Rowe, Erin Eurek, and Kyle Kapchinski of the Texas Transportation Institute are responsible for the key elements of the products. Andrew Griffith of TxDOT, Research and Technology Implementation Division, and Jim Randall and Jack Foster of the Transportation Planning and Programming Division acted as Research Director for the project.

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SUMMARY

The *2004 Urban Mobility Report* (*1*) procedures provide estimates of mobility at the areawide level using roadway link data such as traffic counts and number of lanes. The approach describes congestion in consistent ways using generally available data allowing for comparisons across urban areas or groups of urban areas. Past procedures only looked at projects that added lanes or reduced demand and overlooked many other types of projects that affected the congestion level. This paper describes the extension of the procedures to several operational treatments, to HOV facilities, and the implementation of the procedures with data from the Houston-Galveston area transportation planning model.

This paper describes a framework for incorporating operational treatments and shows effects of those treatments for the year 2000 model. This effort represents an initial attempt at showing the benefits of such projects and programs at an areawide level. The methodology for analyzing the treatments is developing, just as transportation systems are also in a constant growth and development cycle. The results from the analysis could easily change as the research proceeds in this area. Until the operational programs can be incorporated into the model directly, there will be a need for some sort of post-processing step to estimate the delay reduction effects.

The effect of operational treatments can be viewed as proportional to:

- the area of coverage,
- the density of that coverage, and
- the mobility improvement provided by the treatment.

The basis for the congestion estimation methodology is the process used in emissions estimates. The three operational treatment characteristics (area, density, and effect) estimate new values that more accurately reflect the mobility contributions of the treatments. High-occupancy vehicle lanes have not been included in previous mobility estimates, and the operating and ridership statistics can be added to the Houston-Galveston area model outputs.

The area and density factors have been estimated from federal, state and local databases and confirmation of this information has been obtained by local agency reviews. The delay reduction effect of the treatments described below has been developed as a national average, but it could be tailored to the local implementation of the treatment.

1. **Ramp Metering—**Improves the ability of the freeway to maintain relatively high speeds under conditions of high demand and postpones the onset of congestion.
   - **Inputs** to the delay reduction calculations range from a 2.5 percent to 12 percent reduction depending on the congestion level.
   - **Results** show that ramp metering reduced freeway delay by about 145,000 person-hours in 2000 with relatively little metering in place.
2. **Incident Management Programs—**Quickly detecting and removing crashes and vehicle breakdowns reduces delay by returning traffic capacity to normal levels.
   - **Inputs** to the delay reduction calculations ranged from zero to about a 40 percent reduction of incident delay.
   - **Results** show that incident management reduced freeway delay by more than 7.7 million person-hours on the freeways that have incident detection and response strategies.
3. **Traffic Signal Coordination—**Traffic signal coordination programs reduce delay by allowing more vehicles to maintain a smooth flow—particularly in the peak direction.
   - **Inputs** to the delay reduction calculations ranged from less than 2 percent to a 5 percent reduction.
   - **Results** show that signal coordination reduced arterial delay by about 820,000 person-hours in 2000.
4. **Arterial Street Access Management—**Providing smooth traffic flow and reducing collisions is the goal of a variety of individual treatments that make up an access management program.
   - **Inputs** to the delay reduction calculations ranged from zero to 9 percent increase in recurring delay and 9 to 21 percent decrease in incident delay.
   - **Results** show that access management reduced arterial delay by about 1.2 million person-hours in 2000.
5. **HOV Lanes—**Providing reliable high-speed travel improves mobility levels in the 10 corridors where HOV lanes operated in 2000. The HOV lanes are coded as a separate roadway class in the Houston and Dallas-Fort Worth area transportation planning models. The travel volume and speed statistics for the HOV lanes have been added to the freeway and principal arterial street system statistics for each area to produce a combined system mobility performance estimate.

- **Inputs** to the delay reduction calculation for HOV lanes included 10 freeway corridors with HOV data with an average peak period ridership of between 2,500 and 9,700 daily passengers.
- **Results** of the HOV analysis are incorporated directly into the set of performance measures.

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INTRODUCTION

The long-range transportation planning models in Texas urban regions produce estimates of the travel conditions for different transportation and land-use scenarios. These conditions can be further divided into hourly estimates using methods originally developed for air quality work. As a general characterization, these models estimate conditions for a mid-week day with good weather, no incidents, and basic traffic operations treatments (e.g., signs, traffic signals, lane stripes). The list of future transportation projects and programs that many agencies will fund, however, indicates there will be more reliance on operational improvements such as coordinating the traffic signals or clearing collisions from the roads more quickly. Agencies prioritize and select these projects in more detailed processes outside the travel models. Until the effects of these treatments are incorporated into the long-range model outputs, however, it will be difficult to discuss the value of them in the same way that added-capacity projects have been.

The Texas Metropolitan Mobility Plan (TMMP) (*2*) is using a set of travel-time based performance measures to identify system-level congestion estimates. That effort incorporates a spreadsheet developed by the Texas Transportation Institute (TTI) to analyze peak period congestion levels. This paper describes the process for adding the effect of five significant transportation improvement strategies (listed below) to the congestion evaluation spreadsheet developed in the statewide program and applying the process to the regional travel model in the eight TMMP areas to show the potential mobility improvement effects:

- Freeway incident management
- Freeway entrance ramp metering
- Arterial street traffic signal coordination
- Arterial street access management
- Freeway corridor high-occupancy vehicle lanes

CONCEPT DESCRIPTION

The *2004 Urban Mobility Report* (*1*), published annually by the Texas Transportation Institute (TTI), uses a speed, delay, and performance measure estimation methodology developed over several years. While the areawide models use a different dataset and procedures, the performance measures are similar to those used by the Urban Mobility Report. The effects of various transportation improvement strategies can be estimated in terms of reductions in person-hours of travel delay and also converted into reductions in the Texas Congestion Index. Other performance measures can also be used, depending on the analytical or communication needs.

In recent years, the effect of operational treatments has been included in the methodology described in *2003 Urban Mobility Report, Volume 2: Five Congestion Reduction Strategies and Their Effects on Mobility* (http://mobility.tamu.edu) (*3*). The research reports, project evaluations and simulation models examined in that study indicate that the effect of operational treatments is proportional to the person-miles of travel, the congestion level on the treated roadways and the mobility improvement provided by the treatment. The estimates of travel delay can be modified by the three factors listed below to estimate new values that more accurately reflect the mobility contributions of the treatments:

- **Area** covered by the treatment—how much of the system has the treatment?
- **Density** of the treatment within the covered area—how often is the area patrolled, updated, or viewed (particularly as it applies to service patrol programs)?
- **Delay reduction effect**—how much effect does the treatment have?

The area and density factors can be estimated from two national databases and confirmed by local agency reviews. The delay reduction effect can also be tailored to the regional implementation of the treatment. State and local area transportation staff can review the delay reduction factors to ensure reasonableness.

High-occupancy vehicle lanes are somewhat easier to include in mobility performance measures. They are a separate class of roadway in the Houston-Galveston Area Council (HGAC) and North Central Texas Council of Governments (NCTCOG) models. The HOV lane person-miles of travel, travel speed and travel delay can be directly incorporated into the final estimates, whether they are in the model or estimated from field data.

DATA SOURCES

National and local datasets can be used in the estimation process. In addition, the directly collected data from project evaluations or the traffic management centers can be used to either replace or modify any estimates derived in this process in subsequent evaluations. The spreadsheet factors are easily adjusted and, when there are local studies of the effects, they may be preferable. The spreadsheet extends the ability to perform planning level "what if"-type analyses for expanding the operational treatment programs.

The two national datasets that contain regional information are:

- Intelligent Transportation Systems Deployment Tracking Survey (IDTS)—This database provides access to information on the deployment and integration of operations technology gathered through a series of nationwide surveys, beginning in 1996. The IDTS database can be used when specific project information is not available or when future scenario investigations are required. Subsequent sections describe the specific methods used, detailing the congestion reducing effect of each operational treatment *(4)*.
- Highway Performance Monitoring System (HPMS)—HPMS is a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways. The HPMS data are prepared by the Texas DOT and submitted to the Federal Highway Administration *(5)*.

Two analytical procedures have been developed to assist transportation professionals in analyzing the effect of operational treatments:

- Intelligent Transportation Systems Deployment Analysis System (IDAS)—IDAS is a modeling tool that enables the user to conduct systematic assessments and quantitative evaluations of the relative benefits and costs of more than 60 types of ITS investments, in combination or in isolation. This relatively detailed analysis technique was used to study each operating improvement over a range of congestion levels *(6)*.
- Highway Economic Requirements System (HERS)—HERS is an engineering/economic analysis tool that uses engineering standards to identify highway deficiencies and then applies economic criteria to select the most cost-effective mix of improvements for system-wide implementation *(7)*.

CONGESTION LEVEL CATEGORIES

The delay reducing effects of operational treatments vary according to the congestion level on the freeway or street. Most treatments provide more benefits under severely congested conditions, although signal coordination and others not studied in this analysis provide more delay reducing effects when congestion levels are lower and there is more flexibility for rearranging traffic flow. Since the long-range travel models calculate volume-to-capacity ratios for each link of the system, they can be used to estimate the congestion level. Exhibit 1 shows the volume-to-capacity ratios used to identify congestion levels in most Texas regional transportation planning models in the Texas Metropolitan Mobility Plan congestion analysis (*8*).

Exhibit 1. Congestion Level Categories.

Congestion Level	Volume-to-Capacity Ratio
Uncongested	Less than 0.64
Moderate	0.65 to 0.72
Heavy	0.73 to 0.81
Severe	0.82 to 0.90
Extreme	Above 0.90

AREA TYPES

The planning model structure divides each county into many geographic zones. Each zone is characterized by the location and type of development. Most of the models in the Texas metropolitan regions use five types of areas. The area type names might include categories such as central business district, urban, urban fringe, suburban, and rural. The roads in each of these area types have different free-flow speeds, with the urban zones typically having lower speeds than rural areas. The operational treatment deployments are also subdivided by area type in the spreadsheet analysis tool. The treatment descriptions in subsequent sections show the area types numbered 1 (central business district) to 5 (rural).

FREEWAY ENTRANCE RAMP METERING

Ramp meters are traffic signals placed on the entrance ramps of urban freeways. The goal of these signals is to smooth out the flow of vehicles entering the freeway. Groups of vehicles entering a freeway that is nearing a capacity condition can cause the freeway demand to exceed capacity at that one location, while the remainder of the freeway is not over capacity. Stop-and-go traffic, reduced efficiency, and increased accident potential are associated with traffic demand exceeding capacity. The signals can provide some relief from these effects by regulating the flow of vehicles to only that amount that the mainlanes can accommodate without declining into stop-and-go conditions. If vehicles enter the freeway at a uniform rate (for example, one every 3 seconds), the smooth flow of traffic on the freeway can be preserved longer.

ESTIMATING THE DELAY REDUCTION EFFECT

Freeway entrance ramp metering improves the ability of the freeway mainlanes to maintain relatively high speeds under conditions of high demand. Postponing the onset of congestion can significantly improve the average travel speeds over the peak period. While not eliminating peak congestion, if metering can delay the onset of stop-and-go conditions for 15 or 30 minutes, the freeway mainlanes will see congestion benefits. These benefits are gained, however, at the expense of vehicles waiting on the entrance ramps or vehicles using parallel streets instead of the freeway. A few vehicles waiting on an entrance ramp will have slightly longer travel times, but the slowdown that they would cause on the mainlanes would affect many more drivers. When these waiting times are factored into the congestion benefits, the total savings are reduced but not eliminated. Also included in the savings is the delay that can be saved by lower collision rates.

The location of metered freeway sections are included in the HPMS database *(5)*. Congestion level is also identified in the HPMS database. The IDTS dataset *(4)* only indicates the total miles of metered freeway in a region. The transportation management centers also have information about the location of operating ramp meters. The benefits from ramp metering are estimated with information from the HERS Operations Pre-processor *(9)* that incorporates results from the Twin Cities (Minnesota) Ramp Metering Study *(10)*. The Twin Cities study concluded that there was a 3 percent reduction in recurring delay reported for the freeway, entrance ramp and street system, and a 7 percent reduction for freeways-only. The recurring delay benefits also translate into reduction in incident delay based on the current methodology that estimates incident delay using a ratio applied to recurring delay. Exhibit 2 identifies the total delay reduction effect by freeway congestion category.

Exhibit 2. Ramp Metering Benefits in Delay Reduction (HPMS and Deployment Tracking).

Ramp Meter Strategy	Congestion Level				
	Uncongested[1]	Moderate[1]	Heavy[1]	Severe[1]	Extreme[1]
Isolated , pre-timed, centrally controlled or traffic responsive (applies to recurring and incident delay)	2.5%	2.5%	5%	10%	12%

[1]Derived from an equation relating speed to delay reduction for each congestion level.
Sources: HERS Operations Preprocessor (*9*), Minnesota Ramp Metering Study (*10*), and TTI Analysis

Only a few freeways in Texas in 2000 had an active ramp metering program as reflected in the very low percentages listed in Exhibit 3 for ramp metering deployments. Less than five percent of the freeways categorized as being in the urban fringe area type were metered.

The delay reduction factors for the area type and congestion levels were multiplied by the deployment percentages to create a matrix of incident reduction factors. These factors were multiplied by the incident delay estimates for each hour; area type and congestion level percentages were multiplied by the values in Exhibit 4 to estimate total delay savings. The estimated vehicle-hours of delay saved in 2000 according to this estimation procedure are displayed in Exhibit 4.

Exhibit 3. Ramp Metering Deployment Percentages in 2000.

Region	County Number	Area Type	Freeways				
			1	2	3	4	5
Dallas-Fort Worth	5	3	0%	2%	2%	1%	0%
Houston	1	3	0%	2%	2%	5%	10%

Note: Values indicate the percentage of the freeway system in each area type and congestion level that are treated.
Note: All other counties have no ramp metering.

Exhibit 4. Delay Reduction Due to Ramp Metering in Texas Metropolitan Regions.

Metro Region	Daily Delay Reduction (Vehicle-Hours)
Austin	0
Corpus Christi	0
Dallas-Fort Worth	9
El Paso	0
Hidalgo	0
Houston	450
Lubbock	0
San Antonio	0
Total	459

INCIDENT MANAGEMENT PROGRAMS

Approximately half of the delay experienced by travelers in the United States is due to causes other than high volume of traffic. This nonrecurring congestion occurs as the result of traffic accidents, stalled vehicles, spilled loads, maintenance/construction activities, special events, and weather. The California Department of Transportation estimates that for each minute an incident blocks a lane, approximately 5 minutes are added to the total time the freeway will be congested.

The capacity reduction of an incident blocking a lane is greater than the physical reduction in capacity due to motorist "rubbernecking"—slowing down to look at the incident—often on both roadway directions. Although a one-lane blockage out of three lanes translates to a 33 percent reduction in physical capacity, studies have shown an incident blocking a single lane out of three lanes results in a capacity reduction of up to 48 percent. Similarly, a two-lane blockage can reduce the capacity of a three-lane section by as much as 79 percent *(6)*.

One method of combating congestion from nonrecurring incidents is to implement an incident management system, a coordinated and planned approach for restoring freeway capacity as quickly as possible after an incident has occurred. The major elements of an incident management system are: technologies to identify problems and appropriate responses, and clearance methods to notify travelers of expected delays. This typically involves some method of logging cell phone calls; cameras along the roadway to verify the location, severity, and response needed to the incident and radio, websites, and message signs to alert travelers.

ESTIMATING THE DELAY REDUCTION EFFECT

Quickly identifying and removing crashes and vehicle breakdowns reduce delay by returning traffic capacity to normal levels. This analysis seeks to estimate where the freeway is monitored or patrolled and how frequently a service vehicle might patrol past the scene of a crash or breakdown. These factors have been studied in several calculations, but the most comprehensive estimates of the effects are from the Highway Economic Requirements System (HERS) applications *(7)*.

The service patrol programs in each region typically use vans or trucks to patrol the urban portions of the freeway system on weekdays. The patrols have increased over the years as their value has been proven. The system also includes detection programs and cameras. The effects are combined—the cameras verify the problem and allow for more appropriate and quicker response, and the service patrols respond and remove the incident.

The delay reduction percentages, however, are not as easily translated from the HERS model to the transportation planning model analysis methodology. HERS estimates the effect of service patrols as a 25 percent reduction in incident **duration** which, when modeled at the detailed level with HERS resulted in a 65 percent reduction in incident **delay**. The camera systems contributed an additional 4 to 5 percent reduction in incident duration. When both treatments are combined, this would suggest a 30 percent reduction in incident duration and a 70 to 75 percent reduction in incident delay. This is too high to use for an areawide average, judging from the 2001 and 2002 Mobility Monitoring Project reports (*11*,*12*) and service patrol evaluations (*13*,*14*,*15*). For methodology purposes, the planning model outputs were analyzed with a 15 percent reduction in duration and a 35 percent reduction in delay if both cameras and service patrols are present (Exhibit 5).

Exhibit 5. Incident Management Delay Reduction Benefits.

Incident Management Strategy	Congestion Level				
	Uncongested	Moderate	Heavy	Severe	Extreme
Camera verification and roving patrols with each vehicle covering no more than 10 miles of freeway	20%	25%	28%	31%	35%

Source: HERS Operations Preprocessor (*9*) and TTI Analysis

The delay reduction percentages in Exhibit 5 were applied to the deployment percentages (Exhibit 6) to estimate the delay reduction for each congestion level group in each region. Exhibit 7 indicates the resulting delay reduction for each region.

Exhibit 6. Incident Management Deployment Percentages in 2000.

Region	County Number	Area Type	Freeway Congestion Level				
			1	2	3	4	5
Austin	1	1	100%	100%	100%	100%	100%
		2	50%	50%	50%	50%	50%
DFW	2	1	100%	100%	100%	100%	100%
		2	100%	100%	100%	100%	100%
		3	30%	40%	50%	60%	60%
El Paso	1	1	100%	100%	100%	100%	100%
		2	25%	25%	50%	100%	100%
Houston	1	1	100%	100%	100%	100%	100%
		2	100%	100%	100%	100%	100%
		3	30%	40%	50%	60%	60%
San Antonio	1	1	0%	2%	2%	2%	10%
		2	0%	4%	6%	10%	20%

Values note the percent of the freeway system in each area type and congestion level that are treated.

Exhibit 7. Delay Reduction Due to Incident Management in Texas Metropolitan Regions.

Metro Region	Daily Delay Reduction (Vehicle-Hours)
Austin	433
Corpus Christi	0
Dallas-Fort Worth	5,708
El Paso	162
Hidalgo	0
Houston	17,823
Lubbock	0
San Antonio	595
Total	24,721

TRAFFIC SIGNAL COORDINATION

Traffic signals provide an orderly movement of traffic, increase the capacity of intersections, and reduce the frequency of accidents. Making improvements to traffic signals that allow drivers to receive a green signal as they approach an intersection is a program called coordination. This improvement can be one of the most cost-effective tools to increase mobility on arterials. In many cases, traffic signal equipment can be updated to more modern equipment to allow for greater flexibility of timing plans, including coordination with other nearby signals for progression. In some cases, existing equipment may be adequate; however, due to changing traffic patterns, timing plan improvements may be needed to more efficiently handle current traffic flows.

ESTIMATING THE DELAY REDUCTION EFFECT

Traffic signal coordination programs reduce delay on arterial streets by allowing more vehicles to maintain a smooth flow—particularly in the peak direction. The Intelligent Transportation Systems Deployment Tracking Survey (IDTS) dataset *(4)* includes information about the total number of traffic signals managed by the reporting agency and the number of signals controlled from a central location. The Highway Performance Monitoring System (HPMS) dataset *(5)* indicates the presence of signal coordination programs for each street section. Locally the cities, counties and Texas DOT will have information about signal systems that they operate to confirm the reporting in the two national sets.

The Highway Economic Requirements System (HERS) model estimates a maximum delay effect of about 9 percent reduction in recurring delay, based on the set of speed curves in ITS Deployment Analysis System (IDAS) for improvements in technology. These range from reductions of 3 percent for actuated signal control, 9 percent for centrally controlled systems and closed-loop systems, and 20 percent for real-time adaptive signal controls. It might not be reasonable, however, to assume both directions at major crossing streets get a 9 percent benefit, and the delay benefit values in Exhibit 8 have been reduced for this network relationship.

Exhibit 8. Signal Coordination Delay Reduction Benefits.

Signal Strategy	Congestion Level				
	Uncongested	Moderate	Heavy	Severe	Extreme
Traffic Actuated	2%	2%	2%	1.9%	1.5%
Progressive (centralized or real-time)	5%	5%	5%	4.5%	3.5%

Source: HERS (9) and TTI Analysis.

The delay reduction percentages in Exhibit 8 were combined with the signal coordination treatment deployment percentages in Exhibit 9 to create Exhibit 10, the delay reduction factors applied to the arterial street delay estimates created by the planning model. The research team is investigating this finding and anticipates that future estimates may change these percentages, especially as it relates to the other counties.

The vehicle-hours of delay reduction estimated for each region in 2000 (Exhibit 10) indicate relatively modest effects from the limited deployments in the records.

Exhibit 9. Signal Coordination Deployment Percentages in 2000.

Region	County Number	Area Type	Street Congestion Level				
			1	2	3	4	5
Austin	1	1	100%	100%	100%	100%	100%
		2	50	50	50	50	50
Corpus Christi	1	1	100	100	100	100	100
		2	50	50	25	25	0
DFW	2	1	100	100	100	100	100
		2	50	50	80	10	10
		3	25	25	25	25	25
El Paso	1	1	100	100	100	100	100
		2	100	100	50	25	0
Hidalgo	1	1	100	100	100	100	100
		2	100	100	100	50	50
Houston	1	1	100	100	100	100	100
		2	40	50	80	10	10
		3	40	50	80	10	10
		4	40	50	80	10	10
		5	20	25	40	10	10
	2	3	35	30	0	0	0
	3	3	15	15	15	10	10
	8	2	100	50	50	0	0
		3	100	0	0	0	0
		4	100	0	0	0	0
Lubbock	1	1	100	100	100	100	100
		2	100	100	100	50	50
San Antonio		1	100	100	100	100	100
		2	50	50	50	50	50

Note: All other counties are not shown to have signal coordination treatments.

Exhibit 10. Delay Reduction Due to Signal Coordination in Texas Metropolitan Regions.

Metro Region	Daily Delay Reduction (Vehicle-Hours)
Austin	219
Corpus Christi	12
Dallas-Fort Worth	558
El Paso	290
Hidalgo	9
Houston	1,523
Lubbock	0
San Antonio	17
Total	2,628

ACCESS MANAGEMENT PROGRAMS

Providing smooth traffic flow and reducing collisions are the goal of a variety of individual treatments that make up a statewide or municipal access management program. Typical treatments include consolidating driveways to minimize the disruptions to traffic flow, median turn lanes or turn restrictions, acceleration and deceleration lanes, and other approaches to reduce the potential collision and conflict points. Implementing such programs requires a combination of roadway design standards, public sector regulations, and private sector development actions. The benefits of access management treatments are well documented in National Cooperative Highway Research Program (NCHRP) Report 420 (*16*). These benefits are also well known in Texas urban areas with several municipalities having incorporated access management requirements in their development standards. TxDOT has also adopted access management principles for the state highway system.

ESTIMATING THE DELAY REDUCTION EFFECTS

NCHRP Report 395 analyzed the impacts of going from a two-way left-turn lane to a raised median for various access point densities and traffic volumes (*17*). The Texas Metropolitan Mobility Program methodology used tables produced in NCHRP Report 395 to obtain delay factors for both recurring and incident delay.

Raised medians can increase roadway safety by reducing the number of conflict points and managing the location of the conflict points. The reduction in conflict points causes a reduction in crashes. This benefit of the raised medians was included in the delay effects shown in Exhibit 11. The percent reduction factors range from 9 percent at the lowest congestion level to 21 percent at the highest congestion level (*17*). These percent reduction values are applied to the incident delay on the principal arterial streets in the methodology.

There is, however, an increase in recurring delay for through and left-turning traffic when going from a two-way left-turn lane to a raised median. This increase is primarily due to the limitations of left-turn locations. As the turn lanes become full, cars queue into the through lanes and increase the delay of through vehicles. This situation worsens with increased congestion levels and increased signal density (*16*). The delay factors in Exhibit 11 include an increase in recurring delay to account for this queuing and a significant decrease in incident delay due to the reduced collision rate.

Exhibit 11. Access Management Delay Effects.

Access Management Effect	Street Congestion Level				
	Uncongested	Moderate	Heavy	Severe	Extreme
Incident Delay Reduction Percentage	9%	15%	17%	21%	21%
Recurring Delay Increase Percentage	0%	0%	2.5%	5%	9%

Exhibit 12 illustrates the significant use of raised medians on streets in many Texas urban counties. There are several counties that have treated 20 percent or more of their urban and suburban street system with this form of access management. Not all of these miles have a full package—which might also include development regulations, driveway consolidations, turn restrictions, and other programs. But at a planning level of analysis, these deployment statistics can be used to estimate delay benefits.

The delay change values in Exhibit 11 (i.e., incident reductions and recurring increases) are applied to the deployment statistics in Exhibit 12 and result in a net delay reduction in all congestion levels. The total savings are presented in Exhibit 13 for the base year models.

Exhibit 12. Access Management Deployment Percentages in 2000.

Region	County Number	Area Type	Street Congestion Level				
			1	2	3	4	5
Austin	1	1	10%	0%	0%	0%	0%
		2	20	20	20	20	20
		3	30	30	30	30	30
		4	30	30	30	30	30
	2	2	20	20	20	20	20
		3	30	30	30	30	30
		4	30	30	30	30	30
Corpus Christi	1	1	10	10	10	10	10
		2	20	20	20	20	20
		3	20	20	20	20	20
		4	20	20	20	20	20
DFW	1	3	15	15	15	15	15
		4	20	20	20	20	20
	2	1	10	10	10	10	10
		2	30	30	30	30	30
		3	30	30	30	30	30
		4	35	35	35	35	35
	3	2	30	30	30	30	30
		3	30	30	30	30	30
		4	35	35	35	35	35
	5	1	10	10	10	10	10
		2	30	30	30	30	30
		3	30	30	30	30	30
		4	35	35	35	35	35
	6	3	15	15	15	15	15
		4	20	20	20	20	20

Exhibit 12. Access Management Deployment Percentages in 2000.

Region	County Number	Area Type	Street Congestion Level				
			1	2	3	4	5
El Paso	1	1	10%	10%	10%	10%	10%
		2	25	25	25	25	25
		3	30	30	30	30	30
		4	35	35	35	35	35
Houston	1	1	10	10	10	10	10
		2	25	25	25	25	25
		3	30	30	30	30	30
		4	35	35	35	35	35
	2	3	20	20	20	20	20
		4	25	25	25	25	25
	3	3	20	20	20	20	20
		4	25	25	25	25	25
	5	2	30	30	30	30	30
		3	35	35	35	35	35
		4	40	40	40	40	40
	8	2	30	30	30	30	30
		3	35	35	35	35	35
		4	40	40	40	40	40
Lubbock	1	1	10	10	10	10	10
		2	10	10	10	10	10
		3	15	15	15	15	15
		4	15	15	15	15	15
San Antonio	1	1	10	10	10	10	10
		2	15	15	15	15	15
		3	20	20	20	20	20
		4	15	15	15	15	15

Exhibit 13. Delay Reduction Due to Access Management in Texas Metropolitan Regions.

Metro Region	Daily Delay Reduction (Vehicle-Hours)
Austin	446
Corpus Christi	15
Dallas-Fort Worth	1,675
El Paso	248
Hidalgo	0
Houston	1,261
Lubbock	0
San Antonio	247
Total	3,892

HOV LANES

HOV lanes have been a part of the Texas transportation system since 1979. They are exclusive roadways or lanes designated for high occupancy vehicles, such as buses, vanpools, and carpools. The facilities may operate as HOV lanes full time or only during the peak periods. HOV lanes typically require a minimum vehicle occupancy of two or more persons. However, in some locations, occupancy requirements have been raised to preserve the high speeds on the facility. Support facilities such as park and ride lots and transit centers with direct access to the HOV lane are important system elements to increase facility use. HOV lanes may also be used to provide bypass lanes on entrance ramps with ramp meter signals. Several common types of HOV lanes are barrier-separated, concurrent flow, and contraflow lanes:

- Barrier-separated lanes are the predominant form in Houston and are used on the I-35 South Freeway in Dallas. They are most often in the center of a freeway and physically separated from the general-purpose lanes with concrete barriers. Single lane facilities operate as reversible lanes, flowing in one direction during the morning period and the other direction in the evening period. Multiple lane facilities may either be operated as two-way facilities or reversible facilities.
- Concurrent flow HOV lanes (commonly the inside lane) operate in the same direction of flow as the general-purpose lanes and are usually separated from the general-purpose lanes by a small buffer and wide paint stripe. These are seen on I-35 North and US67 in Dallas and the Katy (I-10 West) and Southwest (US 59) Freeways in Houston.
- Contraflow lanes make use of the inside off-peak direction general-purpose lane during the peak period. Movable concrete barriers are used on a few facilities in the United States, including the East R.L. Thornton (I-30) Freeway in Dallas.

ESTIMATING THE DELAY REDUCTION EFFECT

Providing reliable and high-speed travel improves mobility levels in corridors where HOV service is available. The regional transportation agencies have funded data collection activities on the HOV lanes since their opening that can be used for trend analysis. Several of the regional travel models have a separate functional class for HOV roadways that can provide the same level and type of data as the freeways and principal arterial streets. The evaluations and travel model statistics have speed and person travel volume information. The HOV travel statistics can be added to the freeway and principal arterial street system information produced by the regional travel models for the areawide mobility statistics.

High-occupancy vehicle data has been included from five corridors in Houston and five in Dallas in 2000 (Exhibit 14). The passenger-miles of travel (PMT) on the 10 lanes are based on the ridership and the trip lengths on the HOV lanes. There were approximately 1.4 million passenger-miles of travel on the HOV lanes for the six peak hours on an average day in Houston and Dallas in 2000, out of a total of more than 40 million miles on the freeways and major streets in each area.

Exhibit 14. High-Occupancy Vehicle Lane Operating Statistics, 2000.

Freeway Corridor	Peak Period Riders		Average Speed (mph)	Peak Period Person-Miles (1000)	
	Morning	Evening		Morning	Evening
Houston					
Katy	9,000	9,500	58	113	117
North	9,600	8,000	52	185	154
Gulf	6,100	5,000	52	92	81
Northwest	7,000	7,100	57	94	94
Southwest	8,800	7,600	51	101	87
Dallas					
East R.L. Thornton (I-30 East)	9,700	9,300	51	49	47
Stemmons (I-35E North)	3,400	4,300	52	24	17
LBJ (I-635) Westbound	5,200	5,000	59	27	25
LBJ (I-635) Eastbound	3,800	6,600	52	23	39
South R.L. Thornton (I-35E South)	2,500	2,500	60	6	13

Source: Reference *18*,*19*.

CONCLUSIONS

This paper identified the methodology used to incorporate the mobility improving effects of four operational treatments and high-occupancy vehicle lanes. These elements are a key part of the programs that will be deployed to address the growing congestion problem in Texas. The input data needed to estimate the effect of the operational treatments are the amount of system covered by the treatment. In the context of the current regional travel models, this requires an estimate of the percentage of roadway in each area type and congestion level that has been treated. A spreadsheet-based process uses the inputs to estimate the effect in terms of reduced hours of delay and improvements in the Texas Congestion Index.

The initial congestion estimation methodology did not include high-occupancy vehicle lanes. The vehicle-miles and vehicle-hours of travel for HOV lanes are standard model outputs and can be subdivided into hourly estimates with the same process as used with the freeways, tollways, frontage roads, and principal arterials. A different vehicle-occupancy ratio is used with the HOV lanes to estimate person-mile and person-hour statistics. The resulting values are added to those of the other functional classes for a combined system mobility measure.

OPERATIONAL TREATMENT SUMMARY

High-occupancy vehicle lane operations will be added to the freeway and principal arterial street travel statistics. Exhibit 15 summarizes the benefits estimated for the four other operational improvements in each of the eight Texas metropolitan areas in 2000. Approximately 9.9 million hours of delay are saved each year from the relatively modest areawide deployments as estimated by these procedures. This value is lower than the delay reduction benefits reported in the *2004 Mobility Report* (*1*) due to the lower delay values estimated with the TMMP spreadsheet. This discrepancy is being investigated in on-going research; however, the delay reduction percentage in the two methods is similar, indicating the operations “credit” approach should produce useful results.

Exhibit 15. Summary of Delay Reduction Effects for Four Treatments in Texas Metro Areas, 2000.

Strategy	Annual Delay Savings (1000 person-hours)
Freeway Ramp Metering	145
Incident Management	7,725
Signal Coordination	820
Access Management	1,220
Total	9,910

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